Parallel Workflows to Personalize Clinical Guidelines Recommendations: Application to Gestational Diabetes Mellitus

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Abstract—**The MobiGuide system provides patients with personalized decision support tools, based on computerized clinical guidelines, in a mobile environment. The generic capabilities of the system will be demonstrated applied to the clinical domain of Gestational Diabetes (GD). This paper presents a methodology to identify personalized recommendations, obtained from the analysis of the GD guideline. We added a conceptual parallel part to the formalization of the GD guideline called "parallel workflow" that allows considering patient's personal context and preferences. As a result of analysing the GD guideline and eliciting medical knowledge, we identified three different types of personalized advices (therapy, measurements and upcoming events) that will be implemented to perform patients' guiding at home, supported by the MobiGuide system. These results will be essential to determine the distribution of functionalities between mobile and server decision support capabilities.**

Keywords—**m-health, clinical guidelines, personalized care, decision support system.**

I. INTRODUCTION

Clinical Practical Guidelines (CPGs) collect recommendations on the appropriate treatment and care of people with a specific disease and conditions, and they are based on a systematic review of clinical evidence. Care providers can use CPGs for treatment, but time constraints hamper the access to the knowledge accumulated during patient encounters.

Computer-interpretable Guidelines (CIGs) are usually developed based on the text of CPGs [1]. They can be used to support clinicians' decision making processes, by automatically generating recommendations about what medical procedures to perform tailored for each individual patient [2].

A significant amount of knowledge is still left as implicit in CPGs and should be turned into explicit knowledge during the Knowledge Acquisition (KA) process. Some of the implicit knowledge is specific to the local implementing institution, and includes organizational workflow and constraints, goals, and scope. The KA process is usually performed by knowledge engineers (KEs) in collaboration with Expert Physicians (EPs) from the institution at which the CIG is to be implemented.

It is difficult to tailor care workflows to the needs of the individual patient. Implementing CPGs in a decision support system with an interface to an electronic health record (EHR) makes the application of guidelines more personal and more likely to be accepted during clinical care [3].

The EU FP7 funded project MobiGuide (MG) [4] provides patient guidance services based on CIGs supported by an intelligent decision-support system. The system helps patients manage their illness by monitoring disease parameters and providing the appropriate feedback personalized to patients' preferences and context in a mobile environment. The system is based on the best available clinical evidence personalized to the patient's personal circumstances and technological context.

The main components of the MG System are: 1) A backend Decision Support System (DSS) devoted to the representation and execution of CIGs, which is complemented by a mobile DSS that supports the distribution of guideline parts; 2) A Body Area Network (BAN) that provides real-time monitoring of biosignals and communicates with the backend server and; 3) A Personal Health Record (PHR) that is ubiquitously and securely accessible and collects patients' personal and monitoring data. The MG system and its clinical effectiveness will be evaluated in patients with Gestational Diabetes (GD) as one of the application areas.

This paper presents a methodology to identify personalized patient recommendations obtained from the analysis of a specific CPG. The GD local guideline has been elicited to formalize the knowledge representation and to allow creating the ontology specific consensus [5], which describes schematically the interpretation of the GL agreed by both the EPs and the KEs. In this work, we added a conceptual parallel part to the process of formalization that focuses on patient behaviour, called "parallel workflow". The aim was to consider patient context and patient preferences so that we can generate recommendations, warnings or reminders able to guide patients at home supported by the MG system.

II. MATERIALS AND METHODS

In order to elicit the Gestational Diabetes CPG, we implemented the KA methodology that was previously developed and evaluated for the specification of CPGs by EPs and KEs [5, 6].

This methodology starts with choosing the specification language and continues with instructing the EPs about the KA process. Then, the appropriate CPGs for formalization are selected. The EPs of 'Hospital de Sabadell' created the local GD CPG implementation [7]. The process continues with making an ontology specific consensus. This phase is important because although CPGs are evidence based, some actions do not appear in the CPG but are still considered correct by some physicians, and because not all physicians will necessarily consider everything in the CPG as relevant and applicable to the patient. We focused on creating the local consensus and elaborated it with patient-customization, personalization and technological–context aspects. We used a CPG graphical representation iteratively to produce this local consensus.

In order to extract patient-tailored parallel workflows from the CPG, we identified those recommendations that might imply an advice for the patient, typically to be carried out at home (e.g. to measure blood glucose (BG)). Recommendations that imply advice for the patient are also the starting point of a process of care (workflow) that is parallel to the CPG and completely patient-centric. The result of the process is a customized CIG including the recommendations for care professionals and the corresponding recommendations to be addressed to patients (see Figure 1).

Figure 2 shows an example of the parallel workflow applied to GD monitoring plan. In "traditional" CIGs, recommendations 1-5 are directed toward the care professionals, and the care professionals explain them to their patients, but they are not actually applied in a functional automatic manner by a DSS. For example, after enhancing the plan for BG monitoring with a parallel workflow, it now contains recommendations for the patient and can be further

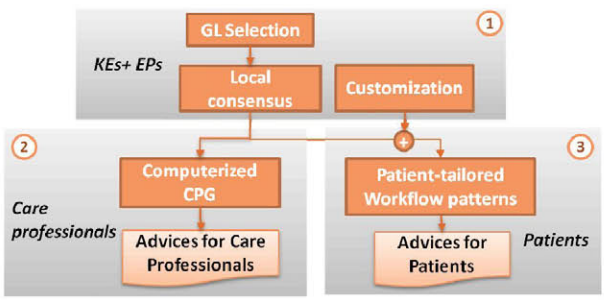

Fig. 1 Methodology for GL formalization and patient-tailored workflow patterns identification that produces a customized CIG

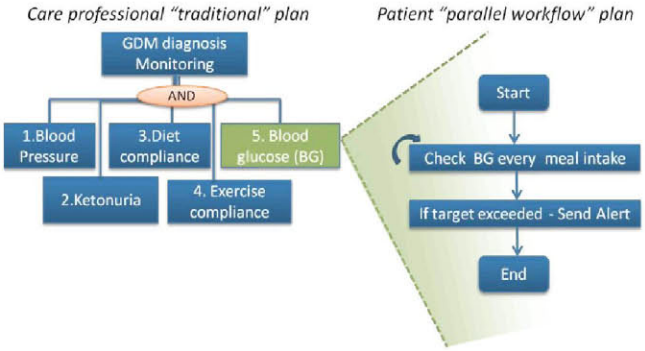

Fig. 2 An example of parallel workflow for BG monitoring

decomposed into a formal monitoring plan which can be executed by the patient's mobile (Smartphone).

III. RESULTS

The analysis of the GD guideline, done by KEs in consultation with EPs of 'Hospital de Sabadell', took a total time duration of 4 months along 10 iterations. It led to the extraction of a set of workflow patterns, related to three types of advices:

A. Therapy Advisors, to Help the Patient to Comply with Her Treatment

Patients with GD are responsible for following therapy prescriptions at home. Therapy prescription in GD is mainly related to three types of recommendations: a) Nutritional therapy; b) Exercise; and c) Insulin therapy.

For some women, showing a good compliance to nutritional and exercise recommendations can avoid to administer insulin. Due to this reason, mechanisms to reinforce the patient's compliance to diet and physical activity could contribute significantly to keep a good metabolic control. Patients with GD are trained to estimate the amount of carbohydrates for each meal so that they can follow nutritional prescription correctly. Also they are instructed to write down in their personal's logbook whether they are not following nutritional prescription or eating forbidden nutrients and the motivation for not following recommendations.

Clinicians check the patient's compliance to diet and exercise during clinical encounters, where they can assess the importance of not following compliance. MG will detect possible situations of non-compliance related to diet and physical activity, and ask the patient for confirmation.

In MG, physical activity practicing and its intensity is detected automatically with a physical activity detector. In order to estimate compliance to diet, the system will need to trust the subjective estimation of carbohydrates for each meal intake.

The parallel workflow pattern for diet and exercise compliance can control the patient's adherence to recommendations. When not following recommendations repeatedly, the

patient will receive an alert to show the importance of following compliance such as: (e.g. "*Try to avoid food with high glucose content such as cakes"* or *"Try to increase the duration of physical activity to improve glycemic control").* Also, patients will receive feedback from the system when they follow recommendations, so that they can feel that their efforts while managing the disease are recognized.

It is especially important to know if the patient is not following nutritional prescription when there are high BG levels, as BG measurements are associated to diet intakes along the day. Patients could receive specific recommendations when one of these situations is detected (e.g. *"Your BG has been elevated associated to high glucose intake, you should follow the recommendations").*

Depending on the side effect of non-compliance, related to exercise and/or diet prescription, the clinician in charge of the patient should be informed.

As in the example in Table 1, patients will be asked specifically about non-compliance related to the presence of high BG levels. Additionally, the patient will be able to write down the reason why she is not following diet recommendations (as in first data entry). When the importance of non-compliance is medium or high and repeated in different days/meal-intervals (as in third and fourth data entries), a clinical decision about therapy might be necessary.

For patients that require insulin administration, insulin doses will be registered to assess compliance. The patient can receive specific reminders about when to administer insulin, following her personalized schedule of meals (considering working days and weekends).

Insulin compliance needs to be monitored to determine the relationship cause-effect when analyzing BG levels. The system will ask the patient about insulin compliance, especially when anomalous BG levels are detected.

Table 2 shows an example of non-compliance related to insulin administration. Patient P_1 presents hypoglycemia levels associated to the administration of an insulin dose

Table 1 Example of non-compliance to nutritional therapy and high BG (* repeated anomalous BG due to non-compliance)

Abs. Time	BG (mg/dL)	Intake	BG moment	Diet	Type of food	Reason	Importance
16/03/2013 22:30	125	Dinner	Post-prandial	+	Cake	Party	Low
16/03/2013 15:30	165	Lunch	Post-prandial	++	Ice cream	-	High
17/03/2013 21:30	148	Dinner	Post-prandial	+	-	Birth-day	Medium*
18/03/2013 21:30	145	Dinner	Post-prandial	++	Double carbs	Skip prev. meal	High*

Table 2 Example related to non-compliance to insulin administration

Abs. Time	**ID**	**BG value**	**Intake**	**BG moment**	**Insulin**	**Reason**	**Importance**
16/03/2013 13:30	P_1	70	Lunch	Postprandial	+1 U	Eat more carbs.	Medium
16/03/2013 15:30	P_2	165	Breakfast	Postprandial	-3 U	Unknown	High
18/03/2013 14:13	P_2	148	Lunch	Postprandial	0 U	Forgot	High
18/03/2013 14:30	P_1	65	Dinner	Postprandial	+2 U	Eat more carbs.	High

higher than recommended in two situations, so she would receive specific recommendations to reinforce the correct therapy use (e.g. *"Administering more insulin than recommended is producing hypoglycemia events").* Patient P_2, instead, seems to be skipping insulin doses and presents repeated hyperglycemia, so she will receive recommendations to reinforce the importance of following prescription.

B. Measurements Advisors, to Remind the Patient to Take Specific Measurements

GD management requires monitoring several variables daily and assessing the results periodically. Usually clinicians perform this process during encounters at the hospital, which happens every week or every two weeks. MG will monitor variables with specific sensors or manually in the Smartphone's logbook. For some patients, MG can be used to remind when each measurement should be performed. Only patients interested in this option will receive reminders about specific measurements such as BG or ketonuria. It is important to take into account that patients should not be overloaded with excessive reminders, as this might have the opposite result than expected. Patients could finish leaving pass messages if they are too demanding for them. Other parameters required to monitor compliance (diet, insulin or exercise) will not be part of this type of reminders.

Also, non-compliance in the process of measurement will be considered for the main clinical parameters (BG, ketonuria, blood pressure). When the patient does not perform measurements frequently enough or when she is not downloading data to the system so that data can be analyzed according to periodic requirements, the patient will be reminded. If the same situation is kept, the patient could be cited to attend an on-site visit, after warning the clinician.

C. Upcoming Event Advisors, for Dealing with Personal Situations

There are several significant personal events that can lead to delivery of GD guideline recommendations in the MobiGuide system. These can be related to situations where the diet, physical activity and schedule of the patient may not be routine, as in an upcoming holiday or party. Respective advisors could be addressed to the patients using the Smartphone interface,

regarding changes to therapy and measurement schedule associated to different types of personalized events.

We have identified several parameters to be personalized by each patient with GD, depending on the specific schedule or the presence of special events (see the example in Table 3). When required, personalization parameters will be supervised by clinicians.

For example, patients could personalize their preferred time to perform physical activity, the intensity level or duration, depending on working days or holidays. The MG Smartphone will allow configuring schedules and registering special events. As a result, the system will adapt reminders to reinforce compliance to physical activity.
Also therapy related recommendations will be modified to consider parameters depending on the patient's personal context. Following the personalized parameters in Table 3, the system will not alert about practicing low intensity physical activity while the patient is in a work travel. When the patient is going to a dancing party, she is increasing her routine level of physical activity and she is eating not recommended nutrients. In this situation, the MG system will not insist on un-compliance but it will account for un-compliance events in case of repetitions.

Table 3 Example: Preferred configuration of upcoming events

	Working days	Holidays	Special event (e.g. dancing party)	Special event (e.g. work travel)
#Required daily BG measurements	4	2-3	Same as holidays	Same as working days
#Required daily ketonuria levels	1	0	1	3
Max. BG ranges (mg/dL)			Same as holidays	Same as holidays
Preprandial	<95	<105		
Postprandial	<130	< 145		
Preferred time to perform physical activity	18:30	11:00	--	Afternoon
Intensity level of physical activity	Medium	Medium	High	Low
Physical activity duration	1 hour	30 min.	2 hours	1 hour
Wake-up time	07:00	10:00	--	08:00
Preferred number of meals	5	6	6	5
High sugar food	--	--	Yes	Yes
Reminders before BG measurements	No	Yes	Yes	Yes

IV. CONCLUSIONS

This work presents three different types of advices (therapy, measurements, upcoming events) extracted from the Gestational Diabetes local consensus guideline, which are parallel to recommendations for clinicians included in the CPG. The process has permitted to define the necessary steps to create a customized CIG that includes personalization to each individual patient including specific preferences and context. The results will help to determine the level at which decisions should be placed in terms of MG DSS (at mobile-side DSS or backend server-side DSS). Those decisions which could be taken by patients self-management will be part of the mobile DSS while decisions that need to be supported by clinicians will be placed in the server DSS. The distribution of DSS capabilities could be also modified depending on patients' customization or on the technological context, such as the absence of connectivity.

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